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Electrical Power Cable Engineering

edited by
William A. Thue

Washington, D.C.



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SERIES INTRODUCTION

Power engineering is the oldest and most traditional of the various areas within electrical engineering, yet no other facet of modern technology is currently undergoing a more dramatic revolution in both technology and industry structure. Among the technologies of growing importance for the 21st century are high, medium, and low voltage power cables. They have become a staple of modern power systems engineering, in which underground transmission and distribution (T&D) systems—out of sight and out of the way—have become the only acceptable way of providing electrical service in urban areas that meets customer expectations for reliable service and low esthetic impact.

For a number of years there has been a surprising lack of good books on up-to-date cable engineering practices. William Thue's *Electrical Power Cable Engineering* certainly fills this gap, with a thorough, well-organized treatment of modern power cable technologies and practices. The book focuses particularly on the medium and low voltage cables, voltage levels that form the bulk of underground systems and which provide the reliable distribution link so necessary to the high quality service demanded by today's electric consumers. At both the introductory and advanced levels, this book provides an above-average level of insight into the materials, design, manufacturing, testing, and performance expectations of electric power cable.

As the editor of the Power Engineering Series, I am proud to include *Electrical Power Cable Engineering* in this important series of books. Like all the books planned for Marcel Dekker, Inc.'s Power Engineering Series, William Thue's book treats modern power technology in a context of proven, practical application and is useful as a reference book as well as for self-study and advanced classroom use. The Power Engineering Series will eventually include books covering the entire field of power engineering, in all of its specialties and sub-genres, all aimed at providing practicing power engineers with the knowledge and techniques they need to meet the electric industry's challenges in the 21st century.

H. Lee Willis

FOREWORD

Electrical cable can be considered as just a conductor with an overlying insulation or an exterior shield or jacket. Perhaps with this naive, simplistic concept is part of the reason that cable engineering, especially for power cable, has been largely neglected in current electrical engineering education in the United States with its emphasis on computers, electronics, and communication. But power cable does electrically connect the world! The history, so interestingly presented in Chapter 1 of this book, shows how the subject evolved with both great success and sometimes unexpected failure.

As this book emphasizes, cable engineering is technically very complex. Certainly electrical, mechanical, and even to some extent civil engineering are involved in interrelated ways. Many other disciplines—physics, inorganic chemistry, organic (primarily polymer) chemistry, physical chemistry, metallurgy, corrosion and with tests and standards in all of these areas—are concerns. Of course, it is impossible in one book to deal with all of these aspects in a completely comprehensive way. However, the various components of power cables are discussed here with sufficient detail to provide an understanding of the basic considerations in each area. Reference to detailed sources provides a means for those with greater interest to pursue specific subjects.

The importance of factors involved in different types of cable installation is stressed. Long vertical cable runs have special problems. Installation in ducts may lead to problems with joints, terminations, elbows, and pulling stresses. At first, cable with extruded insulation was buried directly in trenches without recognition of the then unknown problem of “water treeing” in polyethylene, which was originally thought to be unaffected by moisture. After massive field failures, well over a thousand papers have been written on water treeing! Field failures can involve many factors, e.g., lightning, switching surges, repeated mechanical stressing, and swelling of voltage grading shields in contact with organic solvents such as oil and gasoline. It is important to recognize how such

diverse factors can affect the performance of cable in the field.

Electrical Power Cable Engineering meets a need to consider its complex subject in a readable fashion, especially for those with limited background and experience. Yet sufficient detail is provided for those with greater need in evaluating different cables for specific applications. Most of all, the supplier of materials for cables can obtain a better understanding of overall problems. Also, the experienced cable engineer may come to recognize some of the parameters of materials with which he or she has not worked previously.

*Kenneth N. Mathes
Consulting Engineer
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PREFACE

A course entitled Power Cable Engineering Clinic has been presented at the University of Wisconsin—Madison since the early 1970s. During the intervening years, there have been numerous lecturers and copious class notes that form the basis for much of the material that is contained in this volume. I have attempted to rearrange those notes into a book format. Many sections have been expanded or are entirely new so that the complete story of power cables can be obtained in one book. We hope that this team effort will be a useful addition to the library of all dedicated cable engineers.

The emphasis is on low and medium voltage cables since they comprise the bulk of the cables in service throughout the world. Transmission cables are the ones with greater sophistication from an engineering standpoint. However, all the basic principles that apply to transmission cables also apply to low and medium voltage cables and are therefore included in this book.

An unfortunate fact is that in the rapidly changing environment of power cables, the most recent book published in North America that covered medium voltage cables was the 1957 *Underground Systems Reference Book*, prepared by the Edison Electric Institute. Several excellent handbooks have been published by cable manufacturers and are current, but the broad scope of the 1957 textbook has not been updated since then.

The current volume covers the up-to-date methods of design, manufacture, installation, and operation of power cables that are widely used throughout the world. The audience that would benefit from the highly knowledgeable writings and wide backgrounds of the development team include:

Cable engineers employed by investor-owned utilities, rural electric utilities, industrial users, and power plant personnel

Universities that would like to offer electrical power cable courses

Cable manufacturers that need to provide new employees with an overall view of power cables as an introduction to their companies

This text provides the required information to understand the terminology and engineering characteristics and background of power cables and to make sound decisions for purchasing, installation, and operation of electrical power cables.

William A. Thue

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